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NOTES ON RESERVOIR SILTING AND SUSPENDED-LOAD MEASUREMENTS IN IDAHO

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INTRODUCTION

The storage reservoirs of the United States play a vital role in our industrial and agricultural war production. The domestic and industrial water supply of probably half of our war production centers comes from these reservoirs. One-third of the Nation's power comes from hydroelectric power dams, most of them dependent on storage reservoirs. Much of our irrigated agriculture, which produces many critically needed crops, depends on water storage. Most of our larger dams are now under military guard because their destruction would be a catastrophe, and their continuous function is vital to war production.

In many sections of the United States our storage reservoirs are being rapidly sabotaged by an enemy of our own making--silting that results mainly from accelerated soil erosion. We must maintain a vigilant guard against this insidious form of destruction just as surely as we must guard against damage by enemy agents.

For 8 years the Soil Conservation Service has been studying the effects of accelerated soil erosion on reservoir silting. This report is one of a series of summaries of existing data for different states and drainage basins compiled as a guide for engineers and conservationists who are charged with farm and watershed planning and construction of public and private storage developments.

Fortunately, the State of Idaho, treated in this report, appears to be relatively free of serious reservoir-silting problems, although the available data are admittedly meager. These data are valuable, however, as part of a Nation-wide summary because they do give a general picture of the effects of silting on reservoir operation and on new reservoir construction in this State, and indicate by the absence of existing data the areas in which additional studies are needed.

GENERAL INFORMATION

More than $100,000,000 has been spent in Idaho for the construction of dams and storage reservoirs.

The data included in this report were obtained from various published and unpublished sources, and through field investigations by personnel of the Sedimentation Section of the Soil Conservation Service. In general, quantitative data on sedimentation in Idaho are very limited, but in certain small areas, particularly the Boise River Basin, enough data are available to warrant definite conclusions as to the extent of silting problems.

The only detailed survey to determine the rate of reservoir silting was made on Black Canyon Reservoir on the Payette River by the Sedimentation Section of the Soil Conservation Service in 1936. The drainage area above this reservoir is only 3 percent of the total area of the State.

The only suspended-load measurements that have been continued over sufficiently long periods of time to be of much value in determining the average annual sediment load are those on streams with comparatively small drainage areas in the Boise River Basin and the South Fork of the Palouse River.

The reservoir and silting data are discussed by the principal drainage basins in Idaho. The discussion of each basin includes a general description of the physical features, a summary of known silting data on reservoirs, a summary of other sedimentation data which have a definite bearing on reservoir silting, and a conclusion as to the probable extent of reservoir silting in the basin. Figure 1 shows the location of each principal drainage basin and the reservoirs on which sedimentation studies have been made. A summary of all the known suspended-load data obtained in the State is given in table 2.

UPPER COLUMBIA RIVER BASIN

The Columbia River itself does not flow through Idaho, but three of its main tributaries, the Kootenai, Clark Fork, and Spokane Rivers, either rise in this State or traverse it. The drainage area of the Upper Columbia River Basin, which amounts to about 12 percent of the entire area of the State, is very mountainous and well forested. Elevations range from 2,200 to over 7,000 feet, and the average annual precipitation ranges from 25 inches on the lower areas to some 40 inches in the higher regions. Lumbering is the principal industry in the Kootenai and Clark Fork basins, whereas mining is the principal industry in the Spokane basin.

The most extensive sedimentation problems in this drainage area probably occur in the Spokane River Basin. Tailings resulting from mining activities have been washed into the Spokane River and its main tributaries, the Coeur d'Alene, St. Joe, and St. Marie Rivers. According to the Idaho State Planning Board (4) the sediment deposited in these rivers has raised the levels of their beds near Coeur d'Alene Lake and their flow has become sluggish. Furthermore, considerable silting has taken place at the mouths of the St. Joe and Coeur d'Alene Rivers in Coeur d'Alene Lake.

Suspended-load measurements on the North Fork and South Fork of the Coeur d'Alene Rivers at Enaville, Idaho, have been reported by Stevens (10),1/ and are given in table 2. It would appear from these determinations that the suspended load of the South Fork of the Coeur d'Alene River is very much higher than that of the North Fork.

Stevens investigated the deposition of sediment by the Coeur d'Alene River along a 9-mile reach above Rose Lake, Idaho. Twenty-six cross sections were established and daily water samples taken above and below the reach. In the period May 13, 1921 to June 30, 1922 (414 days), 444,600 tons of suspended matter entered the reach, and 363,100 tons left it, leaving 81,500 tons of suspended matter deposited. The total deposits in the reach, determined from cross sections, amounted to 190,000 cubic yards. Assuming the average specific weight of these deposits to be 65 pounds per cubic foot, the amount of material brought in as bed load and the amount brought in as suspended load are each equal to about one-half of the total. According to Stevens, 75 percent of the suspended load entering the reach consisted of fine silt from ore-reduction works in the Coeur d'Alene mining district, and 25 percent was natural erosional debris.

According to Ellis (1), who visited the Coeur d'Alene River basin in July 1932, mining operations started in this region in 1885. The deposition of rock flour produced by stamp-mill and jig-table processes of mineral recovery, was first evident in the 8 or 10 miles of river below the junction of the North and South Forks. As mining operations continued, the tailings were carried farther down the river to Mission Flat near Cataldo, Idaho, where the river widens and forms a natural settling basin. In 1932, according to

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1/ Refers to literature cited, see page 15.

Ellis, the entire Mission Flat, several square miles in area, was largely covered with mine tailings. The main channel in this region was formerly 40 to 50 feet deep, but soundings in 1932 showed only 12 to 15 feet of water. Silt has been carried into Coeur d'Alene Lake, and deposits can be traced, particularly in the line of flow, between the mouth of the river and the outlet of the lake.

No information is available on the amount of sediment transported and deposited by Clark Fork River.

It has been reported that the Kootenai River carries a large amount of sediment during flood periods. The following statement was made by W. J. Tindale, Designing Engineer for the West Kootenai Power and Light Co. Ltd., in connection with a proposed dam at Granite, B. C., for control of Kootenai Lake (5):

> "Our studies indicate that very little, if any, silt is carried down during the low water period, but that a considerable amount is carried down during the flood deason. Dredging of this deposited material is necessary at Kootenai Landing at intervals in the interests of navigation. The increased velocity of flow due to the lower water surface of the river will have the effect of carrying silt further into the lake and will be of some benefit in keeping the river channel open."

So far as known, no actual surveys have been made to determine the rates of silting of reservoirs in the Upper Columbia River Basin in Idaho. Very little storage has been developed in this basin, as a whole, and major reservoirs are entirely lacking. Available information indicates that reservoirs having a low ratio of storage capacity to drainage area 2/ constructed on the lower reaches of the Coeur d'Alene River probably would suffer rapid silting. Silting rates in most other sections of the Upper Columbia River Basin probably would be lower, although deposits in Kootenai Lake and St. Joe River, and the severe sheet erosion which is taking place in certain parts of the watershed, indicate that on some streams, such as the Kootenai River, a high rate of silting of reservoirs with low capacity-watershed ratio might prevail.

CLEARWATER RIVER BASIN

The area occupied by the Clearwater River Basin amounts to about 11 percent of the total area of the State. The main tributaries of the Clearwater River include Potlatch Creek, North, South and Middle Forks of the Clear River, Locksa and Selway Rivers. The watershed, generally, is very rugged in the higher portions of the basin, but a rolling upland prairie or benchland area, known as Camas Prairie, extends over the western part of the basin. Elevations

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2/ The capacity-watershed ratio, which is usually expressed in acre-feet of storage capacity per square mile of direct tributary drainage area, has been found to be one of the most important factors, generally, governing the rate of silting or annual loss of storage. With all factors affecting the rate of erosion in the drainage area being equal, the larger the watershed for any given size reservoir the greater will be the amount of sediment brought in and the higher will be the rate of capacity loss.

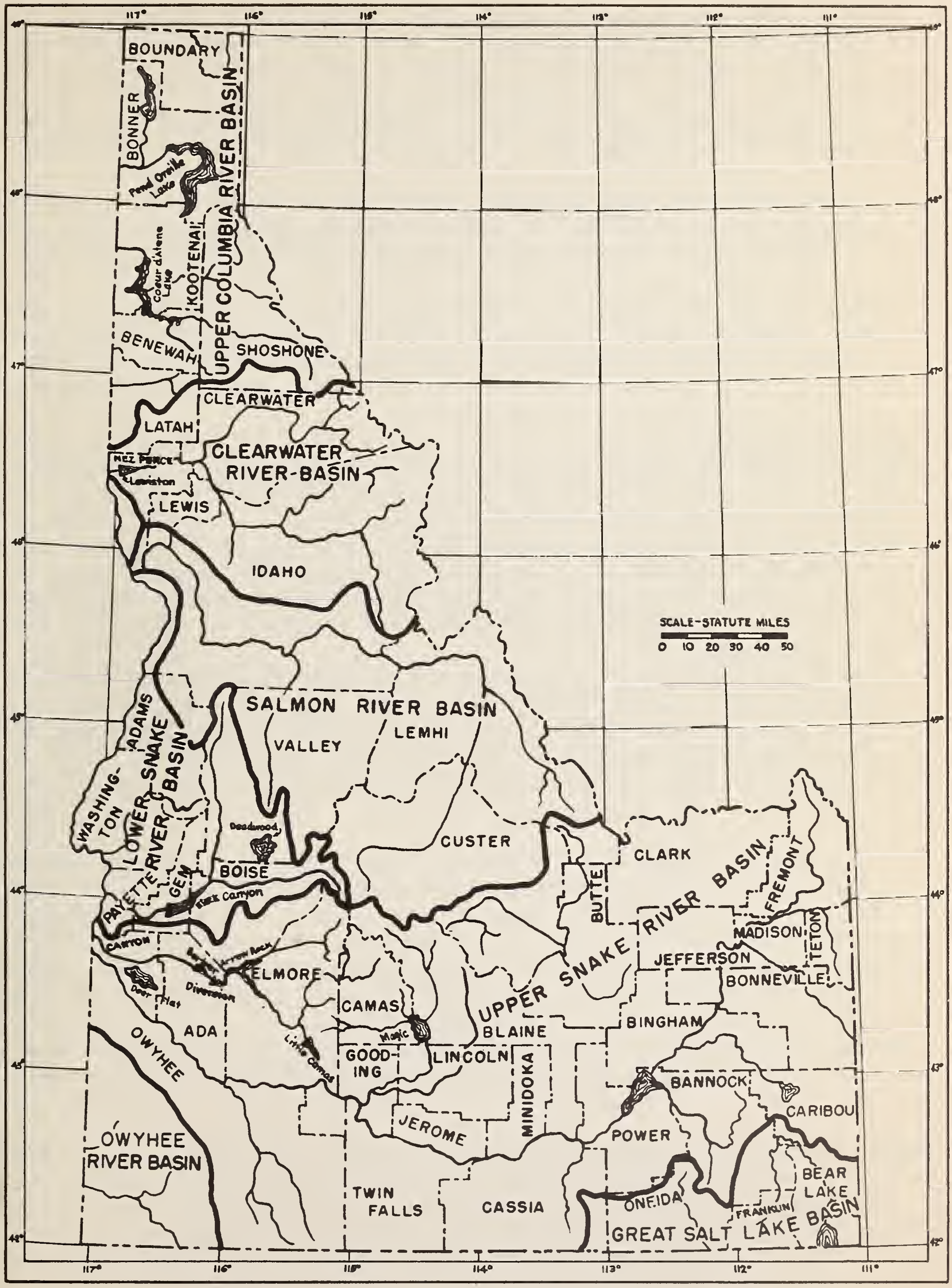

Figure 1.–Reservoirs in Idaho on which sedimentation studies have been made

range from about 700 feet at Lewiston, Idaho, to more than 8,000 feet in the high mountain areas. Average annual precipitation varies from as low as 10 to 15 inches at Lewiston to more than 50 inches in isolated higher mountain areas. With the exception of the Camas Prairie area, and a narrow area along the lower reaches of the Clearwater River, the entire watershed is heavily forested. Lumbering is the principal industry of the Clearwater River Basin.

No major reservoirs exist in the basin. Several dams have been constructed for power production and several others for irrigation, storage and diversion, but the storage capacity developed by these dams is not great.

According to the Idaho State Planning Board (4), sheet erosion of agricultural lands on the plateau areas in this basin is a serious problem. They also state that the Clearwater River carries a considerable amount of sediment during high-water periods.

According to Thomson (11), the lake-fed streams of the higher reaches of the various tributaries carry little sediment; but the lower tributaries, which drain a very different type of topography and surface cover, are often torrential and bring down great quantities of sediment during flood periods. Erosion in these tributary areas has been greatly accelerated since many of the slopes have been bared by logging activities and by burns. The extent of erosion in the Clearwater basin and its effect on filling up the reservoirs above the Lewiston Generating Station Dam have been described by Thomson.

The Lewiston Generating Station Dam is located on the Clearwater River, 2 miles above the junction of this stream and the Snake River. The concrete arch gravity dam, completed in 1927, is owned by the Washington Water Power Company. It is 34 feet high and 1,105 feet long, and forms a reservoir with an area of 780 acres. The reservoir was first filled with water in February 1927.

During the floods of December 1933, considerable sediment was carried into the pond, and suction dredging became necessary to maintain a required depth for logging purposes. A contour map was made of the sediment deposits in the pond area used for logs at the lower end of the reservoir before dredging operations began. According to calculations by Thomson, in 6 years 253,777 cubic yards of fine sediment had been deposited in the area mapped, which included only 66 acres out of the total 780-acre area of the reservoir. It is his belief that the sediment deposit undoubtedly extended from the mapped area to the head of the pond, although it grades from the fine silt in the lower part of the reservoir to cobbles found in the upper end.

The drainage area above the dam is approximately 9,500 square miles, which includes 7,700 square miles of forest land, 480 square miles of logged-off or burned-over land, and 892 square miles of grass-covered foothills or breaks. Thomson indicates that much of the sediment carried into Lewiston Reservoir was probably derived largely from watersheds of the lower tributaries.

It is not unusual for a reservoir which has an extremely low capacity-watershed ratio, such as the Lewiston Reservoir, to fill very rapidly with sediment. There are several instances where such reservoirs have completely

filled during a single flood period. Construction of reservoirs with a low capacity-watershed ratio on some of the lower tributaries in the Clearwater River basin may result in a high rate of silting.

SALMON RIVER BASIN

The Salmon River basin occupies nearly 17 percent of the area of Idaho. The main tributaries are the South and Middle Forks of the Salmon River and the Lemhi River. The watershed consists of rugged mountains and deep canyons. Elevations range from 803 feet at the mouth to more than 10,000 feet in the headwater regions. Average annual precipitation varies from less than 10 inches in the valley section above Salmon, Idaho, to more than 50 inches in the Sawtooth Mountains. With the exception of the valley section above Salmon, Idaho, which is covered generally with sagebrush, and a limited area of grassland along the Salmon River near the mouth, the watershed is well forested, with much of the area located in National Forests.

No major reservoirs have been constructed in this basin. With the execption of several comparatively small irrigation and power dams, storage is largely undeveloped.

No information is available on the rates of silting of existing reservoirs in the Salmon River basin, and no suspended-load determinations have been made that would give a reliable estimate of the probable rate of silting of existing or proposed reservoirs.

Munns, Chapline, Forbes, and others (12), report that a cloudburst in 1932 on Loon Creek caused a heavy runoff on a burned-over area which, in turn, caused a heavy deposit of sand and debris in this stream that destroyed fishing for at least several years. They also report that a similar rain in 1932 on a burned-over area on Richardson and Mann Creeks gutted stream channels and swept debris down into the main stem of the Salmon River. The deposit below Mann Creek dammed the river to a depth of 20 to 25 feet, causing a temporary rapids to be formed.

This information offers no indication as to the probable rate of reservoir silting in this basin, but it does serve to point out that reservoirs constructed below well-forested watersheds could become rapidly filled with sediment if the timber in these areas were entirely removed by burning or logging.

LOWER SNAKE RIVER BASIN

The Lower Snake River Basin includes the main stem of the Snake River and smaller tributaries below the mouth of the Owyhee River. The largest of these tributaries are the Payette, Weiser, and Palouse Rivers. The headwater areas of the tributaries are usually well forested, but on the rolling foothills and plains along the Snake proper and along the Weiser and Payette Rivers, the cover is mainly sagebrush. Grassland predominates on the area bordering the main stream in the lower part of the basin. The average annual precipitation ranges from 10 to 15 inches in the region of the main stream to more than 50 inches in the mountainous headwater regions of the tributaries. The lowest elevation, where the Snake River leaves the State, is less than 900 feet and

the highest elevations exceed 10,000 feet in the mountainous headwaters of tributary streams. Agriculture is the principal industry along the main stream and in the lower parts of the watersheds of tributary streams, whereas lumbering and mining are important in the mountainous areas. Severe sheet erosion and gullying are known to be active in parts of the Payette River watershed and, to some extent, in the Weiser River Basin. Moderate sheet and wind erosion occurs on the grassland area bordering the lower part of the Snake River and in the Palouse River watershed.

The Soil Conservation Service (3), in June 1936, made a detailed survey of Black Canyon Reservoir on the Payette River to determine the rate of silting. Black Canyon Reservoir is located 5 miles northeast of Emmett, Idaho, is owned by the Government and operated by the U. S. Bureau of Reclamation. It is formed by a concrete gravity dam 94 feet in height above stream bed and 1,134 feet long. The dam, completed in June 1924, forms a reservoir which is 8.8 miles long, 1,069 acres in area, and 37,659 acre-feet in capacity. It is used for irrigation storage and diversion.

The watershed area extends over 2,540 square miles, the greater part of which is well forested and mountainous with elevations as great as 10,700 feet. Soils are coarse-grained residual and generally shallow over most of the area. Farming is practiced to some extent on valley flats. Overgrazing of very steep slopes of youthful topography is the principal cause of erosion. The mean annual rainfall varies from 20 to 26 inches.

The maximum sediment thickness found during the survey was 23.2 feet, and the total sediment deposited in 12 years was calculated to be 4,037 acre-feet, or 10.72 percent of the original storage capacity. The average annual rate of silting, 0.89 percent, is moderately high.

The sediment accumulation of 13.2 acre-feet annually per 100 square miles of drainage area is low. Estimates, based on the nature and distribution of deposited sediment in the reservoir, indicate that the rate of accumulation per unit area of drainage for Squaw Creek (drainage area 350 square miles), the principal tributary to the reservoir, is nearly twice that of the Payette River watershed. The moderately high rate of silting of Black Canyon Reservoir is a reflection of a low capacity-watershed ratio of 14.83 acre-feet per square mile of drainage.

Two dams, Grimes Pass and Deadwood, are located in the watershed above Black Canyon Reservoir, and an inspection was made of these reservoirs in connection with the sedimentation survey of Black Canyon Reservoir. Grimes Pass dam, near Garden Valley, Idaho, on the South Fork of the Payette River, is 50 feet high and 200 feet long. Originally constructed in 1909, but washed out since, and replaced, it is used for power development. In June 1936 sand was visible within a few feet of crest level except in the vicinity of the turbine intake, where a suction pump is employed to remove sediment and discharge it below the dam. From these observations it is concluded that practically the entire load of the river had been carried over the dam for several years prior to the time of inspection.

Deadwood Reservoir is located on Deadwood River, a northern tributary of the South Fork of the Payette Riber. It is owned by the Government and operated

by the U. S. Bureau of Reclamation for irrigation storage. The concrete arch dam, which was completed in April 1931, is 700 feet long and 160 feet high at the spillway, and impounds 164,000 acre-feet of water. The watershed area is 110 square miles. Investigation of this reservoir revealed a virtual absence of fine sediment, but occasional deposits of coarse sand were found at several points. In the 5 years that this reservoir had been in operation, the storage loss was negligible, due in considerable measure, to the extremely high capacity-watershed ratio.

Stabler (9) reported intermittent suspended-load sampling of the Payette River during the period May 15 to September 15, 1906, at Horseshoe Bend, Idaho. These measurements showed a maximum sediment load of 2,370 tons per day on June 29, 1906, while for a period of nearly a month, from July 8 to August 4, no perceptible sediment was transported.

The U. S. Geological Survey, in cooperation with the Soil Conservation Service, made sediment measurements on the South Fork of the Palouse River at several stations in the vicinity of Pullman, Washington. More than two-thirds of the drainage of the South Fork of the Palouse River, above the upper sampling station, is located in Idaho. The sediment production per 100 square miles of drainage area (see table 2) above the upper station averaged 22.7 acre-feet annually (assuming a dry weight of 60 pounds per cubic foot) for a 6-year period, and is very nearly the same for the lower station. This would indicate that the sediment production from this area is moderately low for the country as a whole, but probably higher than for most parts of the Northwest. These measurements represent only the suspended load and not the total load carried by this stream.3/ Even though the bed load amounted to 40 percent in this stream, the total load would still be only moderate.

The detailed sedimentation survey of Black Canyon Reservoir indicates that the rate of silting on some of the streams in the Payette River basin would be high for reservoirs which have a low capacity-watershed ratio. Reservoirs located in this basin, which have well-forested watersheds, will suffer relatively little damage by silting. Suspended-load measurements in the Palouse River basin indicate that reservoirs in that basin which have a low capacity-watershed ratio will also experience a high rate of silting.

UPPER SNAKE RIVER BASIN

The Upper Snake River Basin in Idaho includes the main stem of the Snake River and tributaries above the Owyhee River basin. The larger part of the area consists of the Snake River plains, which are covered mainly with sagebrush. The headwater regions, with elevations up to 10,000 feet or more, are rugged mountains, generally well forested. A grassland belt is located in the foothill area between the mountains and plains. Precipitation varies from less than 10 inches in the areas bordering the main stream to more than 50 inches in isolated mountainous areas. Agriculture is the major industry. According to the 1940 Census (16), there are more than 33,000 irrigated farms in the basin, and the

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3/ Many streams in this section of the United States have a high percentage of bed load, which is usually not determined when suspended-load measurements are made.

irrigated area of these amounts to more than 1,000,000 acres.

Wind erosion occurs over much of the area and severe sheet erosion and frequent gullies occur over extended areas in the lower part of the basin.

More than 90 percent of the total storage developed for irrigation in the State of Idaho is located in the Upper Snake River Basin. There are a number of major storage reservoirs in the basin, the largest being American Falls Reservoir located in Power County.

Studies of sedimentation have been made in the Boise River Basin in connection with the flood control survey of this watershed by the U. S. Department of Agriculture. Sedimentation problems in this basin include silting of various irrigation canals, silting of the Arrowrock and other smaller reservoirs, and possibly aggradation of the Boise River channel.

Arrowrock Reservoir was constructed by the U. S. Bureau of Reclamation on the Boise River in 1915. It is formed by a 348-foot concrete gravity and arch dam, 1,100 feet long. The original storage capacity was 291,500 acre-feet and the reservoir, when full, covered an area of 2,888 acres. The drainage area above the dam extends over 2,225 square miles.

According to the Boise project official of the Bureau of Reclamation, as reported by Love and Benedict in 1940 (6), storage loss in Arrowrock Reservoir has amounted to 5,000 or 6,000 acre-feet. Renner (8) gives an estimate, based on water-storage data, of 7,500 acre-feet of sediment deposited in the reservoir between 1915 and 1927, or 12 years. On the basis of sediment-load measurements by the U. S. Geological Survey for the Department of Agriculture on the Boise River near Twin Springs and on Cottonwood and Grouse Creeks near Arrowrock Reservoir for the period January 17 to June 30, 1939, the U. S. Bureau of Reclamation (13) estimated that the sediment load of the Boise will average 460 acre-feet annually. The observed rate of accumulation in Arrowrock Reservoir, according to this same source, has averaged 300 acre-feet annually between 1915 and 1935.

An investigation of Arrowrock Reservoir in 1938, by E. M. Flaxman of the Sedimentation Section of the Soil Conservation Service, revealed that from 0 to 3 feet of sediment had been deposited on the flat lava benches in the reservoir, while the channel itself was scoured clean. A study of his field notes indicates that the thickness of sediment in some parts of the reservoir, such as the delta area, may have exceeded 4 feet, but because of the mechanical nature of the sediment, his measurements may have included only the finer material and not the coarser beds which are not easily penetrated by sampling equipment when submerged.

Arrowrock Reservoir is sluiced periodically, which might be considered an explanation for the difference between the estimated average annual sediment load of the Boise River of 460 acre-feet and the average annual observed rate of accumulation of 300 acre-feet reported by the U. S. Bureau of Reclamation. The estimate of 460 acre-feet, however, is based on such a short period of measurements that it cannot be considered too well supported. Table 1, taken from Love and Benedict (6) gives a record of sluicing from Arrowrock Reservoir between 1919 and 1937. No information is available concerning the amount of sediment removed from the reservoir during these sluicing periods.

Table 1.--Record of sluicing from Arrowrock Reservoir

Year	Period of sluicing	Number of days	Average discharge
			Second-feet
1919	Sept. 13-17, Sept. 20-Oct. 1	17	576
1920	Sept. 13-Oct. 10	28	721
1922	Sept. 19-Oct. 22	34	701
1924	Aug. 19-Oct. 15	58	439
1926	Sept. 16-Oct. 16	31	518
1928	Oct. 8-21	14	704
1929	Oct. 20-31	12	608
1931	Oct. 13-Nov. 7	26	548
1933	Oct. 16-30	15	597
1934	Oct. 14-24	11	569
1935	Oct. 22-25	4	566
1937	Oct. 10-25	16	607

Sixteen miles below Arrowrock, there is a 68-foot rubble masonry dam, known as Diversion Dam, which was completed in 1908 by the U. S. Bureau of Reclamation to divert water for irrigation purposes. Immediately below Diversion Dam, there is a 27-foot timber crib and earthfill dam which forms the Barber Mill pond. This dam is used by the Idaho Power Company for power development. In reference to the Barber Mill pond, Renner (8) wrote:

> "The mill pond of the sawmill at Barber, Idaho, several miles below the Arrowrock Dam, is almost completely filled with silt. In spite of semiannual sluicing, silt has also accumulated above the mill pond until the effective head of water for a hydroelectric plant situated there has been reduced by one-third, or from 30 feet to approximately 20 feet...."

This condition was confirmed by Flaxman in 1938, who also found the 2.3-mile reservoir above the Diversion Dam upstream almost filled with sand and fine gravel. Each fall, the sediment in the reservoir above Diversion Dam is sluiced out through the dam which is provided with gates for this purpose. The sediment is carried down and deposited in Barber Mill pond. Sediment usually remains in Barber Mill pond until spring, when it is partly sluiced out naturally by flood waters or by lowering

the flash boards. A certain amount of the sediment above Diversion Dam is carried through the intake into the New York Canal. According to Love and Benedict (6), the amount of sand removed by draglines or other means from the New York Canal between 1926 and 1940 amounted to 61,000 cubic yards.

An inspection of the backwater area of the two arms of Little Camas River Reservoir, on the South Fork of the Boise River, by Flaxman in 1938, indicated that silting in this reservoir was slight. The reservoir has a storage capacity of 23,000 acre-feet and an extremely high capacity-watershed ratio of 719 acre-feet per square mile of drainage.

Flaxman, in 1938, made a few measurements of silt thickness in Deer Flat Reservoir. This off-channel reservoir is formed by 2 dams in a natural saddle 7 miles south of Caldwell, Idaho. Water is diverted from the Boise River and carried to Deer Flat Reservoir by the 10-mile New York feeder canal. The earthfill dams completed in 1908 are 73 and 53 feet high, and 4,000 and 7,500 feet long, respectively. The storage capacity of the reservoir is 177,000 acre-feet, and the area 9,835 acres. The maximum sediment depth measured was 4.9 feet. The observations indicated that there is an appreciable amount of sediment deposited in the deeper parts of the lake near the dam; but since there is a large amount of dead storage in the lake, it is believed that silting has not yet become a menace.

The Anderson Ranch Dam, which will form a new multiple-purpose storage reservoir with a 500,000-acre-foot capacity, is now under construction by the U. S. Bureau of Reclamation on the South Fork of the Boise River. It is to be of earth and rockfill, and, when completed, will have a height of 340 feet and a length of 1,350 feet. A volume of 30,000 acre-feet, or 6 percent of the total storage capacity of the reservoir will be allocated for silt control (13). The total dead storage of 60,000 acre-feet at Anderson Ranch Dam is believed to be sufficient to provide for all the sediment load of the South Fork of the Boise for several hundred years. The capacity-watershed ratio of this reservoir is extremely high, amounting to more than 500 acre-feet per square mile.

Suspended-load measurements made by the U. S. Geological Survey for the U. S. Department of Agriculture in the Boise River Basin are given in table 2. Sediment production in the various parts of the basin, in a 12-month period, July 1, 1939-June 30,1940, ranged from a maximum 190 acre-feet per 100 square miles of drainage on Grouse Creek to 1.1 acre-feet per 100 miles of drainage on the main stem of the Boise at Dowling. The rate of sediment production bears a definite relationship to watershed conditions. Maximum production was found below areas of seriously depleted range land and from burned, cut-over or placered forest lands. These measurements indicate, as borne out be several reservoir investigations, that reservoirs with even a moderate capacity-watershed ratio would suffer a high rate of silting if constructed on certain streams in the Boise River basin.

Very little information is available on silting conditions of reservoirs located in other parts of the Upper Snake River Basin. There are several rather large areas where severe sheet and wind erosion is known to be taking place, notably in the western part of this basin. An area of severe sheet erosion and slight wind erosion with frequent gullies is located in the head-

waters region of the Bruneau River, one of the main tributaries of the Snake River.

The only information available on reservoir silting in this basin relates to Magic Reservoir on the Big Wood River. This reservoir is formed by a 129-foot earthfill dam completed in 1909. The reservoir has a surface area of 3,472 acres, a storage capacity of 191,500 acre-feet and a watershed area of 1,500 square miles. The watershed is largely mountainous, with elevations reaching 12,000 feet in the headwater regions. Soils consist of basaltic fine sandy loams and most of the area is in forest, with some pasture.

Magic Reservoir was visited by T. L. Kesler of the Sedimentation Section during May 1936. Although no systematic reconnaissance survey was made to determine the approximate amount of sediment in the reservoir, enough information was obtained by him to indicate that the rate of silting of this reservoir is very low. A number of measurements to determine sediment thickness were made along three ranges located 1,500 feet, 4,000 feet, and 11,000 feet above the dam and at several other points in the reservoir. In one measurement the sediment was found to be 1.1 feet thick, whereas in all other measurements it was found to be either absent entirely or existing only as a trace. Measurements along the other ranges of the reservoir also showed an absence of sediment. A measurement in the Wood River branch, near the head of the reservoir, showed a thickness of 1.0 foot. No significant deltas are in the process of formation at the heads of the branches. The very low rate of silting is due in part to the moderately high capacity-watershed ratio of 128 acre-feet per square mile of drainage, and in part to the well protected watershed conditions.

According to the U. S. Army Engineers (14) floodwaters of the Snake River and tributaries in the vicinity of Heise, Idaho, cause considerable damage by scour and deposition of sediment on farm lands. They report that the dam, created across the Gros Ventre River by a landslide in June 1925, failed by sloughing in May 1927, and released some 50,000 acre-feet of stored water, which moved unusual quantities of drift that further aggravated unusual flood effects and caused damage to farms in this area. This was, of course, a purely accidental phenomenon. The Snake River debouches from a canyon in this area and flows between low banks along the top of its alluvial cone on a bed of sand and gravel. There is repeated danger that the Snake River will break out of its present unstable channel to flow in a new one.

The only suspended-load measurements in the Upper Snake River Basin, exclusive of those made in the Boise Basin in 1939-40, are the measurements at Weiser, reported by Van Winkle (19). They indicate that the suspended load of the Snake River Basin at Weiser, Idaho, for the period August 11, 1911 to August 14, 1912, amounted to only 3.1 acre-feet per 100 square miles of drainage. If this represents the approximate average annual suspended load of this stream, then the rate of silting of a reservoir on this stream would be low, even though the bed load amounted to as much as 50 percent of the total load and the capacity-watershed ratio was low. It is believed, however, that many of the tributaries have a much higher suspended-load content than is indicated by the observations at Weiser.

Because of its size and shape, the American Falls Reservoir forms an effective sediment trap, and practically all of the suspended load and bed load carried into it probably is being deposited. A determination of the annual accumulation of sediment in this reservoir would be a good measure of the average sediment production of the headwater portion of the Snake River Basin. The capacity-watershed ratio of this reservoir is 106 acre-feet per square mile of drainage. This suggests that unless the average sediment production for the entire drainage area above American Falls Reservoir is moderately high, the rate of silting of this reservoir is probably low.

OWYHEE RIVER BASIN

A third of the total drainage area of the Owyhee River is located in Idaho. This area covers the southwestern corner of the State, which is characterized by rolling upland topography and lava canyons. The cover is mostly sagebrush and grasslands, with some woodland areas. Grazing and farming on limited irrigation areas are the principal agricultural activities in this basin. Severe sheet erosion with frequent gullies and, in places, slight wind erosion are taking place over nearly half of the area located in this State.

Very little information is available relative to transportation and deposition of sediment by the Owyhee River. According to Van Winkle (19) the sediment load at Owyhee, Oregon, from August 11, 1911 to August 14, 1912 amounted to 397,800 tons. The drainage area above this station is 11,100 square miles. It is not known what portion of this is derived from that part of the watershed located in Idaho.

The following is taken from "The Western Range" (15, p. 310):

> "In Idaho and Oregon the slopes of many drainage basins of the Owyhee River are badly eroded and streams which formerly flowed between grassy banks are now seeping along through sandy washes or flowing through raw cuts with steep, sloughing sides. On foothill tributaries of the Snake River in this general region both sheet and gully erosion are also very evident..."

The extent and seriousness of reservoir silting in this basin are undetermined.

GREAT SALT LAKE BASIN

A comparatively small area of southeastern Idaho, known as the Bear River Basin, drains into the Great Salt Lake of Utah. This area in general is mountainous, with broad valleys. Elevations range from about 5,000 feet to over 9,000 feet. Agriculture is the leading industry and much of the cultivated area is irrigated.

No information is available relative to the transportation and deposition of sediment in this basin. According to the Idaho State Planning Board (4), it is believed that silting is a problem in this basin.

CONCLUSIONS

The available data on silting of reservoirs in Idaho are not sufficient to permit comprehensive conculsions as to the extent of damage by principal drainage basins, nor do they allow adequate estimates to be made of the probable rate of silting of proposed reservoirs. It has been determined, however, that certain areas of high sediment production do occur and that reservoirs located on streams draining these areas are likely to lose their capacity rapidly, especially if they have a low capacity-watershed ratio. Mining operations, depletion of vegetal cover by burning, logging, overgrazing of range land on steep slopes with loose soils, and, in limited areas, cultivation, are the principal factors causing accelerated erosion and increased sediment production. The principal existing storage developments in Idaho are located in the Upper Snake River Basin, and heavy reservoir silting, if it does occur, would assume greater importance in this basin than in others in the State.

An analysis of published and unpublished data for Idaho indicates that in many cases a high percentage of the total sediment loads of streams in this region is transported as bed load. Any estimates of reservoir silting rates that are based on suspended-load measurements only, therefore, would probably be much too low unless proper consideration is given to the amount of bed load carried into the reservoir.

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Table 2.—Suspended-load determinations of streams in Idaho

Drainage basin, stream and station	Drainage area	Period	Suspended matter during period	Annual suspended matter[1]	Annual sediment per 100 square miles of drainage	Reference number
	Square miles		Tons	Acre-feet	Acre-feet	
Upper Columbia River Basin						
North Fork Coeur d'Alene River at Enaville, Idaho	------	5/13/21-6/30/22	146,000	----	----	(10)
South Fork Coeur d'Alene River at Enaville, Idaho	------	5/13/21-6/30/22	615,000	----	----	(10)
Clearwater River Basin						
None	------	------------	------	----	----	----
Salmon River Basin						
None	------	------------	------	----	----	----
Lower Snake River Basin						
Payette River at Horseshoe Bend, Idaho	2,240	5/15/06-9/13/04	(2)----	----	----	(9)
South Fork Palouse River near Pullman, Washington	81.1	6/ 1/34-5/31/35	19,603	15.0	18.5	(7)
		6/ 1/35-5/31/36	36,468	27.9	34.4	(7)
		6/ 1/36-5/31/37	26,367	20.2	24.9	(7)
		6/ 1/37-5/31/38	12,766	9.8	12.0	(7)
		6/ 1/38-5/31/39	28,775	22.0	27.2	(7)
		6/ 1/39-5/31/40	20,533	15.7	19.4	(7)
Average annual			24,065	18.4	22.7	
South Fork Palouse River at Pullman, Washington	132	6/ 1/34-5/31/35	32,708	25.0	19.1	(2)
		6/ 1/35-5/31/36	57,190	43.8	33.2	(2)
		6/ 1/36-5/31/37	46,629	35.7	27.0	(2)
		6/ 1/37-5/31/38	20,963	16.0	12.2	(2)
Average annual			39,373	30.1	22.8	
Upper Snake River Basin						
Bannock Creek near Idaho City, Idaho	4.5	1/16/39-6/30/39	3/ 14	----	----	(17)
		7/ 1/39-6/30/40	3/ 730	.6	12.4	(6) and (18)
Boise River near Twin Springs, Idaho	830	1/17/39-6/30/39	52,156	----	----	(17)
		7/ 1/39-6/30/40	4/ 71,266	54.5	6.6	(6) and (18)
Boise River at Dowling Ranch near Arrowrock, Idaho	2,220	1/17/39-6/30/39	13,057	----	----	(17)
		7/ 1/39-6/30/40	32,629	25.0	1.1	(6) and (18)
Boise River near Boise, Idaho	2,610	5/26/05-4/30/07	(5)----	----	----	(9)
Boise River at Notus, Idaho	3,820	1/13/39-6/30/39	87,488	----	----	(17)
		7/ 1/39-6/30/40	122,316	93.6	2.5	(6) and (18)
Cottonwood Creek near Arrowrock Reservoir, Idaho	21.4	1/23/39-6/30/39	3/ 718	----	----	(17)
		7/ 1/39-6/30/40	3/ 8,067	6.2	28.8	(6) and (18)
Cottonwood Gulch at Boise, Idaho	16.0	1/27/39-6/30/39	3/ 24,806	----	----	(17)
		7/ 1/39-6/30/40	3/ 15,017	11.5	71.8	(6) and (18)
Elk Creek near Idaho City, Idaho	13.1	2/ 4/40-6/30/40	6/ 2,826	----	----	(6)
Elk Creek near Idaho City, Idaho	22.3	1/20/39-2/ 4/40	6/ 12,288	----	----	(6), (17) and (18)
Granite Creek near Idaho City, Idaho	4.8	1/18/39-6/30/39	3/ 2,933	----	----	(17)
		7/ 1/39-6/30/40	3/ 1,927	1.5	30.7	(6) and (18)
Grouse Creek near Arrowrock, Idaho	8.0	1/20/39-6/30/39	3/ 27,633	----	----	(17)
		7/ 1/39-6/30/40	3/ 19,909	15.2	190.4	(6) and (18)
Mocre Creek near Idaho City, Idaho	37.0	1/20/39-6/30/39	5,019	----	----	(17)
		7/ 1/39-6/30/40	6,288	4.8	13.0	(6) and (18)
Moore Creek near Idaho City, Idaho	119	1/28/39-6/30/39	17,119	----	----	(17)
		7/ 1/39-6/30/40	43,722	33.5	28.1	(6) and (18)
New York Canal near Barber, Idaho	------	2/ 1/39-6/30/39	4/ 38,669	----	----	(17)
		7/ 1/39-6/30/40	89,788	----	----	(6) and (18)
Pine Creek near Idaho City, Idaho	6.1	2/13/40-6/30/40	3/ 7,345	----	----	(6)
Pine Creek near Idaho City, Idaho	6.5	1/16/39-2/12/40	3/ 596	----	----	(6), (17) and (18)
Snake River near Wieser, Idaho	74,900	8/11/11-8/14/12	3,042,000	2,327.8	3.1	(19)
Owyhee River Basin						
None	------	------------	------	----	----	----
Great Salt Lake Basin						
None	------	------------	------	----	----	----

[1]Dry weight of a cubic foot of sediment assumed to be 60 pounds.
[2]Intermittent sampling, maximum daily sediment load, during period, 2,370 tons per day, on June 29.
[3]Includes bed load.
[4]Includes bed load from Febru ry 10, 1940 to June 30, 1940.
[5]Intermittent sampling, maximum daily sediment load, during period, 5,600 tons per day from April 8-13, 1907.
[6]Includes bed load from February 4, 1940 to June 30, 1940.